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MAGNETOSPHERIC SPACE PLASMA INVESTIGATIONS

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by

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Probably the most significant milestones during this reporting period were the completions of UAH Ph. D. dissertations by Drs. David Brown, Chi Wing Ho, Joyce Lin, and Xinbo Zhang, each carrying out research partially supported under this grant. The Ph. D. degrees were all conferred in December, 1993. Titles of the dissertations were:

David Brown - *A Generalized SemiKinetic (GSK) Model for Mesoscale Auroral Plasma Transport* [Ref. 1]

Chi Wing Ho - *The High-Altitude Polar Wind: Simulation and Observation* [Ref. 2]

Joyce Lin - *Equatorial Heating Effects on Outer Plasmasphere Evolution* [Ref. 3]

Xinbo Zhang - *Ray Tracing Study of Magnetospheric ULF Wave Propagation* [Ref. 4]

Several papers have emerged and will emerge from these dissertations; the current ones are discussed below.

SCIENTIFIC INVESTIGATIONS

O^+ Outflows

A systematic study of the effects of **E** × **B** convection heating on O^+ upflows in the high latitude F-region ionosphere has been carried out. Simulation cases were performed for both solar minimum and solar maximum atmospheres for values of the convection electric field ranging between 50 and 200 mV/m. Results of this study were compared with similar studies done with hydrodynamic and generalized transport models and important differences were noted. These study results were also compared with radar and satellite data, and good agreement was found with some of the data. The results of this investigation were written up and submitted to JGR [Ref. 5].

We have also completed the study of the quasi-statistical properties of outflowing O^+, through bulk parameter analysis of DE-1/RIMS observations when DE-1 was in the midaltitude polar cap magnetosphere. We employed a technique which relies on analysis of the DE-1 radial head RPA data near the magnetic field direction for obtaining the O^+ bulk parameters of density, temperature and flow velocity from these measurements. We analyzed thirteen passes and tested our technique with reasonably good confidence in the derived parameters. This work completed the basic research work for the Ph. D. dissertation of Mr. C. W. Ho [Ref. 2]. Results are nearly ready for submission to GRL [Ref. 6]

Generalized SemiKinetic Model

A new project was initiated which involves a comparison of RIMS data with generalized semikinetic simulation results. Specifically, the density, drift speed and spin curve skew for H^+ and He^+ ions in the polar cap, ionosphere-magnetosphere transition region (the polar wind acceleration region) from the RIMS data are being compared with the corresponding simulation quantities. It is anticipated that an AGU talk on this subject that will be presented to the Spring AGU Meeting.

During this period our study comparing the H^+/electron polar wind expansion into near-vacuum and the evolution of density perturbations, in the form of altitude-localized density cavities and enhancements, for the hydrodynamic and semi-kinetic models appeared in JGR [Ref. 7]. In general, we have found that there is significantly less tendency to form shocks and steep gradients in the semikinetic model than in the hydrodynamic model; owing to ion velocity dispersion, such steep gradients tend to dissipate in the semikinetic description. We have also found increasing divergence between the two approaches generally as higher moments are considered; in particular, the parallel temperatures often deviate significantly. It has been found, for the types of outflow situations considered, that the inclusion of heat flow has a major effect in bringing to closer agreement the parallel temperature profiles for the hydrodynamic and semikinetic models. A short paper on a slightly different aspect of the comparison will also appear in the proceedings of the MIT Geoplasmas workshop [Ref. 8].

We have completed development of a dynamic semikinetic model for examining the synergistic effects of waves and magnetospheric hot plasma populations on the outflowing ionospheric plasma. This was done by imposing hot bi-Maxwellian ion and electron distributions at the top of our auroral simulation flux tube(4 R_E), as well as a spectrum of waves with altitude which perpendicularly heat the ionospheric ions. For example, when the hot ions are more strongly peaked at $\alpha = 90°$ than the hot electrons, a positive potential develops at the top boundary, hence downward electric fields. With transverse wave heating below, this leads to a dynamic and partially self-consistent version of the "pressure cooker" concept proposed by Gorney et al.[Ref. 9]. This formed part of the Ph. D. dissertation of David G. Brown [Ref. 1], and it is being readied for submission to JGR [Ref. 10].

Another interesting semikinetic study appeared in GRL [Ref. 11]. It concerns steady-state profiles of polar wind densities matched with the DE-1 total density profile of Persoon et al. [Ref. 12]. In this study, we used densities and drift velocities from low-altitude (2000-4000 km) polar wind observations of Chandler et al. [Ref. 13] as exobase O^+/H^+ parameter inputs for our semikinetic simulation. We found that if the combination of assumed base ion and electron temperatures is around 14,000 K (e.g., T_e=9000 K, T_i = 5000 K), the resulting polar wind steady-state density profile is dominated by O^+ to beyond 8 R_E, and that we obtain a virtually perfect match with the power law profile $n_e = 490\ r^{-3.85}$ cm^{-3} observed in electron densities by Persoon et al. [Ref.12].

Field-Aligned Flows and Distributions

Our semikinetic modeling study of the effects of equatorial heating and electrostatic hemispheric decoupling on early L = 4 core plasma evolution appeared in JGR [Ref. 14]. In this paper, we considered asymmetrical northern/southern hemispheric ionospheric flows and incorporated a generalized transport description for the electron population, which allows for consideration of electron heating effects and a more realistic calculation of electric fields produced by ion and electron temperature anisotropies. The combination of equatoriallyconcentrated perpendicular ion heating and parallel electron heating leads to an electrostatic potential peak about the magnetic equator which tends to shield and decouple ion flows in the northern and southern hemispheres. Unequal ionospheric upflows in the northern and southern hemispheres lead to development of distinctly asymmetric densities and other bulk parameters. Termination of particle heating causes the reduction of equatorial potential and allows interhemispheric coupling. When the inflows from the ionospheres are reduced (as may occur after sunset), decreases in plasma density near the ionospheric regions are observed, while the heated trapped ion population at the equator persists. A brief version of related work for the MIT Geoplasmas workshop is in press [Ref. 15], as is the invited paper on general L = 4-7 core plasma evolution [Ref. 16].

During this period we completed a statistical study of the latitudinal distributions of core plasmas along the L = 4.6 field line using DE1/RIMS data. We studied those orbits for which the spacecraft was approximately skimming this L-shell, and for which the low-energy ions were trapped distributions at the equator and counterstreaming off the equator. We analyzed approximately 40 such orbits, and characterized parameters such as the ratio of equatorial-trapped to 45° flux or equatorial anisotropy, the latitudinal half-width of the anisotropy, the transition latitude where ions exhibit significant anisotropy, the penetration ratio of field-aligned fluxes in the vicinity of the equator to outside the transition, and the latitudinal scale length of the trapped ion flux variations near the transition latitude. Various types of occurrence frequency relationships have been deduced. Perhaps the most interesting result is that we find an inverse relationship between the equatorial anisotropy and the penetration ratio. This is understood as the result of enhanced positive electrostatic potential associated with increased ion equatorial anisotropy producing a reduced equatorial penetration of the field-aligned ions. These results formed the final component of the Ph. D. dissertation of Joyce Lin [Ref. 3] and are being prepared for submission to JGR [Ref. 17].

ULF Wave Ray-Tracing

The effects of heavy ions (O^+ and He^+) seen in the propagation of Pc1,2 and Pc3 fast mode waves are also seen in Alfven mode waves. Since these waves are constrained to travel along magnetic field lines, deeper penetration toward the Earth also means propagation to higher latitudes. In addition, the different nature of the waves makes interpretation of the wave propagation more complex. The initial part of this study has been completed and formed a substantial part of the dissertation research of Dr. Xinbo Zhang [Ref. 4]. A paper describing the results of the study of fast mode wave propagation for Pc3 waves appeared in JGR [Ref. 18] and a paper on the corresponding Alfven mode results is in preparation for submission to JGR [Ref. 19].

Plasmasphere-Ionosphere Coupling

A short paper on dual spacecraft estimates of ion temperature profiles and heat flows in the plasmasphere-ionosphere system has been prepared and is being readied for submission to *Planetary and Space Science* [Ref. 20]. In this study, we examined a limited set of DE1/DE2 conjunctions and used the temperatures obtained at two altitudes along specific field lines to integrate a simplified heat conduction dominated equation for the variation of temperature along the magnetic field lines. The resulting temperature profile is used to estimate the ion heat fluxes into the ionosphere as well as compare the profile with additional temperature points from "multiply-crossed" L-shell observations. The ion heat fluxes are observed to be in the range of 10^{-8} - 10^{-7} Joules/m^2/sec for the inner plasmasphere and up to 10^{-5} Joules/m^2/sec in the outer plasmasphere. Also, we find some cases where the additional data points on the "multiply-crossed" L-shell sets lie fairly close to the temperature profile obtained by using the highest and lowest DE1/DE2 temperature points as boundary conditions.

ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

Empirical Model

Final changes have been made to the automatic processing methods and data output formats. Large scale testing is ready to commence, followed by comprehensive analysis of the RIMS data set.

MEETINGS

Drs. Horwitz and Brown attended the Fall AGU Meeting in San Francisco, where Dr. Horwitz presented one invited paper on Generalized SemiKinetic Models [Ref. 21] and was co-author on three other papers [Ref. 22-24] and Dr. Brown presented one invited paper on Mesoscale Auroral Plasma Transport [Ref. 24] and was co-author of another [Ref. 21]. Dr. Horwitz also convened a series of special sessions on Dynamics of Auroral Plasmas.

PUBLICATIONS

In addition to those noted above, the following papers are at the indicated stage in the publication cycle:

Papers published are those on:
Electrostatic charging of ring dust clouds [Ref. 25]; and a meeting report on the Guntersville Magnetospheric Plasma Models workshop [Ref. 31].

Papers accepted and in press are those on:
RIMS observations of ion pitch angle distributions at high latitudes [Ref. 26]; anomalous night-time ionospheric electron temperature events [Ref. 27]; effects of centrifugal acceleration of the polar wind [Ref. 28];comparison of semikinetic and hydrodynamic models for plasma flow on closed magnetic field lines [Ref. 29]; and plasma transport using semikinetic models [Ref. 30]

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